BLM LIBRARY
88049405

DISTURBANCE HISTORY AND ESTABLISHMENT OF LOBLOLLY PINE IN THE CONGAREE SWAMP

FINAL REPORT

Subagreement No. CA-5240-3-9001/2
Cooperative Agreement No. CA-5000-2-9007

August 24, 1994

NEIL PEDERSON
Joseph W. Jones Ecological Research Center
Route 2, Box 2324
Newton, GA 31770

and

ROBERT H. JONES
School of Forestry
Auburn University, AL 36849

ID 88049405

QK
494.5
.P66
P434
1994
C. 2

INTRODUCTION

The establishment of pine forests occurs mainly through large-scale disturbances such as catastrophic fire (Heinselman, 1973; Romme, 1982), agriculture (Quarterman and Keever, 1962) and large blowdowns (Foster, 1988). Smaller disturbances, especially ground fires, perpetuate pine dominance (Garren, 1943). In the absence of fire, pines are often succeeded by hardwoods (Quarterman and Keever, 1962) which in turn further reduce the likelihood and intensity of fire (Christensen, 1981).

Loblolly pine (*Pinus taeda* L.) is extremely abundant in the southeastern United States and is one of the first tree species to re-vegetate an area after disturbance (Quarterman and Keever, 1962). Because it produces numerous, widely dispersed seeds, loblolly has become established over large acreage of abandoned agricultural lands and heavily logged forest (Quarterman and Keever 1962; Lorio et al., 1972). Most loblolly forests established after major disturbances are even-aged (Quarterman and Keever 1962). However, before the advent of large-scale agriculture and logging, loblolly pines existed primarily as scattered individuals and small groups (Mohr, 1896; Ashe, 1915) that may or may not have been even-aged. The means by which loblolly maintained itself in the pre-European landscape is unclear.

The Congaree Swamp National Monument in central South Carolina contains extensive acreage of old-growth loblolly pine forest which affords an opportunity to study pre-settlement loblolly pine forest dynamics (Smathers 1980). The size and age of these pines are unusual in today's landscape (Helm et. al., 1991). Many occur as scattered individuals or small clusters as described for pre-settlement forests. However, there are some relatively large, dense stands of loblolly which leads to the hypothesis that a large disturbance event in the past created conditions favorable for their establishment. Fire, abandoned agricultural land (e.g., from very early or pre-European cultures), and blowdowns have been suggested as the key disturbances that established loblolly stands in the Congaree (Swailset. al., 1957; Dennis, 1975).

The primary objective for this project was to determine the event(s) that might have led to the establishment of the loblolly pine stands in the Congaree national Monument. Our null hypothesis was that even-aged stands were formed in response to a major disturbance event (most likely fire) that removed the forest canopy, and altered the forest floor to expose mineral soil and destroy rootstocks of potentially competitive hardwoods. Investigation of this hypothesis was accomplished through estimation of stand age

structure, survey of seedling density in areas disturbed by logging and Hurricane Hugo, and sampling of the vegetation.

METHODS

Stand Selection, Vegetation Sampling

Hurricane Hugo moved through the Monument in September 1989 destroying up to 50% of the loblolly pine/mixed hardwood forest (Putz and Sharitz, 1991). Therefore, in oredr to reconstruct undisturbed loblolly pine stand characterisitcs, a precondition for study site selection was the presence of standing, live trees in relatively undisturbed patches. Stands (patches) selected were one to several hectares in size, concentrated in the northwest portion of the Monument, and variable with respect to vegetation and topography (Figure 1, Table 1). Levels of hurricane damage (Table 1) ranged between light (essentially none) to moderate (25% of canopy trees down or dead).

Within each stand, six 0.053 ha, circular subplots were used for estimating pre-hurricane species composition and structure. Subplots were centered around an upper canopy loblolly pine within a patch of relatively undisturbed trees. Subplots for two of the stands were chosen differently. In the SREL Plot #4, a one ha area was sampled and mapped by R. R. Sharitz in the fall of 1989. To standardize the SREL Plot #4 with the other old-growth stands, data were obtained from 0.053 ha subplots centered on six randomly chosen loblolly dominants. In the Young Pine stand, seven 0.053 ha subplots were randomly selected from two randomly placed transects. Though distinctively younger than the old-growth stands, the Young Pine stand was included in this study as a possible model of loblolly stand regeneration. The stand has strong evidence of having developed after agricultural abandonment.

In all stands, species and DBH of trees (stems >10.9 cm DBH) and saplings (stems ≥2.5 cm and <10.9 cm DBH) were recorded within the six subplots. Total area sampled for trees and saplings was therefore 0.32 ha per stand (except 0.37 in the Young Pine stand and 1.00 in SREL Plot #4). Vegetation data (not discussed in this final report) are shown in Tables A-N.

Loblolly Pine Stem Mapping and Evidence of Fire

All loblollies within each stand (but only those within subplots in the Young Pine stand) were tagged and their diameter was measured at 1.3 meters above the ground (DBH). The base of each loblolly was checked for fire scars and microsite topography (hummock, hollow, or flat) was noted. Stem maps were created to assess the spatial distribution of trees and tree ages (see below). For SREL Plot #4, a map of the entire one ha stand was provided by the Savannah River Ecology Laboratory. In each stand, the upper 5 cm of soil was excavated from several subjectively placed microplots to look for charcoal.

Age Determination

Age of an individual stand was determined by coring at least one-quarter of the tagged pines with a 71 cm (28") increment borer with an inside diameter of 5.15 mm. Of the 213 loblollies tagged in all seven plots, 71 were cored. For each cored tree, two cores were pulled as close to ground as possible, usually at 0.5 meters. Cores taken at least 90^0 apart increase the chances of locating missing or partial rings (Swetnam et. al., 1985).

After being mounted in the field, the cores were brought to the Savannah River Ecology Laboratory to be air dried and sanded. Ring counts were performed on each core. For cores that missed the pith, age was estimated by the method described by Arno and Sneck (1977). Finally, tree ages were then mapped spatially to reveal the disturbance history of the loblolly pine stands (Heinselman, 1973).

Seedling Surveys

Loblolly pine seedling densities were estimated within a Hurricane Hugo blowdown located approximately 100 meters south of the Elevated Boardwalk stand. Twenty-five 50 m^2 seedling regeneration plots (total sample area of 0.12 ha) were randomly located along transects placed randomly east to west. Only loblolly seedlings were tallied. Observations were made on microsite conditions and whether each seedling was free to grow.

A similar survey was carried out in an area of the Congaree where all sawtimber sized trees (i.e., with DBH ≥ 30 cm) were removed in 1972. The former logged area is located just south of the bluff line approximately 2.5 kilometers west of the Elevated Boardwalk stand. Twenty-five plots of 50 square meters each were sampled for loblolly regeneration. The regeneration plots were randomly placed on transects running east to west. Loblolly pine saplings were tallied and all tree species that had regenerated in the plots were noted.

Data gathered from both seedling surveys were extrapolated into the future using mortality rates to determine how many pines will exist at different times during the recovery from disturbance. Extrapolated numbers were then compared to densities of pines in existing old-growth stands. If the current seedling populations (especially in the hurricane blowdown) were adequate to produce future stands with densities matching current old-growth forests, then overstory removal without forest floor disturbance would have to be considered a viable hypothesis for the regeneration of the loblolly pine stands in the Congaree.

RESULTS AND DISCUSSION

Age of Individual Trees

From the results of the pith estimation technique, we were able to age over 90% of the loblolly pines to within plus or minus seven years of true age (Tables 2 and 3). Age estimates ranged between 33 and 227 years.

Within each stand, diameter was a poor indicator of tree age. When all seven stands are lumped together, a stronger trend was seen (Figure 2). However, some notable variations still occurred. For example, the fourth and fifth largest loblollies (129 and 125 cm in diameter, respectively) were only 114 and 128 years old, while a 157 year old tree had a diameter of only 59 cm. Furthermore, trees in the Young Pine Stand clustered around age fifty had similar diameters to those clumped around age 60 (Figure 3). The largest tree in these groups, 60 cm in diameter, was 51 years old while the smallest stem, 21 cm in diameter, was 58 years of age. From this data, extrapolating age from diameter in old-growth loblolly pine would be very imprecise.

Distribution of Ages Within Stands

The seven stands exhibited a variety of stand age structures. The Tall Pines stand was clearly even-aged (Table 3). The remaining stands included two-age and uneven-age structures (Figures 4 to 9). At Cedar Creek, small clumps of even-aged patches were apparent adjacent to older trees (Figure 4). This spatial pattern is also seen in SREL Plot #4 (Figure 5). Here it appeared that the younger age class existed within an older remnant stand. In contrast with the latter stands, the Weston Lake and Kingsnake Trail stands had highly mixed distributions of ages. Neighboring loblolly pines differed in age by up to thirty years at Weston Lake (Figure 6) and by a little less than twenty years at Kingsnake Trail (Figure 7). The Young Pine stand (Figure 8) showed a distinct spatial separation of age

classes. The boundary followed a west/northwest to east/southeast direction. The 51 year age group was to the north while the 63 year age class was to the south. The older trees, probably relic fence-row pines, are found on northwest boundaries of the stand and between the two transect lines that the subplots were set on. The Elevated Boardwalk Stand had an age pattern similar to the Young Pine Stand. The younger stems were distinctly separated from the older stem aged (Figure 9).

Overall, the age class distributions found in this study are in contrast with our original predictions of even-age structure. If just size classes were considered, stands with diameter distributions similar to the Elevated Boardwalk, SREL Plot #4 , Tall Pines, and Young Pine would be interpreted as even-aged (Lorimer, 1985), especially since loblolly pine is shade intolerant. It is not surprising, therefore, that Swails et. al. (1957) and Stalter (1971) concluded on the basis of size class distributions, that the loblolly stands in the Congaree were even-aged. However, when age and size are pltted together and when spatial distributions of ages were plotted, only the Tall Pines stand was clearly even-aged. The number of age groups in the other old-growth stands ranged from 2 (Elevated Boardwalk) to 5 (SREL Plot #4).

Results of this study show that loblolly can reproduce successfully in the Congaree floodplain not only at an intermediate scale, >0.3 ha (Tall Pines stand), but also in small gaps, possibly as small as single tree replacement (Weston Lake stand). Some patches of even-aged trees in stands, especially in the Cedar Creek (Figure 4), SREL Plot #4 (Figure 5), Tall Pines, and Elevated Boardwalk (Figure 9) stands, could be the result of "girdle farming." Farmers as late as the early 1900's in Alabama would girdle and farm around large trees instead of clearing large tracts of land (Harper, 1943). This type of farming might have been practiced in the Congaree before the introduction of oil based farming.

Spatially distinct age groups within a stand may represent multiple regeneration events following a single major disturbance. In the Young Pine stand, two groups of loblolly pine regenerated over a 20 year time period (Figure 8). Because of frequent disturbance (flooding) and microsite differences in the Monument, it is possible that one wave of regeneration occurred on higher microsites and a second wave occurred when lower sites dried out later. An alternative hypothesis is that the two age groups could represent two different disturbance events. Differences of more than 20 years could possibly be the result of the release of advanced regeneration (Lorimer, 1985). An age distribution covering 150 years was found in a forest less than 30 years after a hurricane disturbance (Henry and Swan, 1974). An age structure such as this for loblolly pine at

Congaree is highly unlikely because of loblolly's intolerance of shade and the intense plant competition that occurs in floodplain forests.

In two of the oldest stands, Weston Lake (Figure 6) and Kingsnake Trail (Figure 7), single tree replacement of loblolly appears to have occurred. This is best represented in the Weston Lake stand where a 114 year old tree is within 20 meters of a tree 146 years of age. Single tree replacement of the loblolly in these stands indicates that loblolly will be maintained at lower densities for an extended period of time or until another major stand replacement event occurs.

Effects of Hurricanes and Logging

Cohort establishment dates of loblolly pine at the landscape level were identified and compared with hurricane dates for South Carolina (Ramsay, 1809; Tannehill, 1952; Kovacik and Winberry, 1987) (Figure 10). No relationship between hurricanes and the establishment of loblolly pine was visible. To test whether a statistical relationship existed, the number of trees established per decade was correlated with the number of hurricanes per decade using two time frames: decades ending in the number 0 (1871-1880, 1881-1890, etc.) and number 5 (1876-1885, 1886-1895). Correlation coefficients (r values of 0.23 and -0.47 respectively) were not significant ($p>0.05$) for either time frame.

Seedling regeneration in the blowdown and logged areas appeared to be inadequate to produce stands similar to those studied in 1992 (Tables 4, 5, and 6). Loblolly seedling density in the blowdown area was 157/ha with only 35/ha free to grow. Densities in the logged area were 14/ha total with 11/ha free to grow. Using a 3.3% mortality rate, the projected number of loblolly per hectare surviving up to 200 years into the future was below densities found in extant stands studied and very few, if any, trees will exist beyond age 100 (Table 4). However, when the conservative mortality rate of 0.4% was used, more pines would live past age 100, but the density of pines free to grow would still be lower than the density of upper canopy pines in the existing stands (Table 5).

When new stands were projected forward and the old-growth stands were projected to an intermediate age of 60 using the 0.4% mortality rate, the Elevated Boardwalk stand had densities of loblolly pine similar to those hurricane blowdown area. The logged area still did not regenerate sufficient numbers to produce projected stands similar to these existing stands 1993 (Table 6).

A forest like the extant loblolly pine stands might regenerate in the blowdown area if the mortality rate is equal to or lower than 0.4% annually. However, a rate of 0.4% (observed for stands with low densities) is not realistic for natural stands where densities are high and competition is severe (Allen, 1961; Somers et. al., 1980; Peet and Christensen, 1987). Seedling densities (pine plus hardwoods) in the blowdown area are unknown, but are presumably higher than 618 stems/ha. Calculations of loblolly seedling survival using a more realistic annual mortality rate of 3.3% predicted that few of the sampled loblolly seedlings would survive.

It is possible that the number of loblolly seedlings were regenerated during the year following Hurricane Hugo was adequate to recreate the existing old-growth stands. However, the severe floods of 1992-93 and the drought in the summer of 1993 reduced what little loblolly pine that had regenerated by 1992 in the hurricane blowdown area.

Effects of Fire

No fire scars or charcoal were found during the study in the old-growth stands. Charcoal was found in the Young Pine stand, but the fire that occurred in this stand was most likely man-induced. Also, the spatial distribution of age lead us to believe to that fire did not play a role in the establishment of the loblolly forest. The ages indicate that a large-scale fire was not vital for the creation of most of the stands in the Congaree. However, fire can not be entirely ruled out. Lack of charcoal in the old-growth stands could result from export of charcoal out of the system or burial under imported alluvium that could be as much as 2 meters deep (Gail Wagner, personal communication). A proposed fire hypothesis for the establishment of the loblolly pines stands could be of a severe blowdown and accumulation of necromass followed by a prolonged drought creating potential fire conditions. Anecdotal writing describes long droughts in South Carolina preceding hurricanes (Ramsay, 1809; Simms, 1840). Simms wrote of a hurricane hitting Charleston in 1696 followed by a great fire. A study to examine sediments in Weston Lake and deep soil could help to clarify if fires were associated with loblolly establishment in the Congaree.

SYNTHESIS

Based on the inadequate regeneration seen in the two natural regeneration experiments, the absence of fire scars, and the lack of correlation between loblolly

establishment dates and historical hurricanes, we conclude that fire and large blowdowns are not the primary causes for establishment of loblolly pine stands in the Congaree Swamp. However, the hypothesis that major canopy disturbance coupled with forest floor disruption is necessary for loblolly regeneration was supported by the natural regeneration in the logged area where all of the observed loblolly pine saplings had regenerated on skid roads. Other studies have shown that skidding, which exposes mineral soil, leads to stimulation of loblolly regeneration (Grano, 1949).

Since fire was apparently not the means by which the Congaree stands were regenerated, we believe that at least some of them were initiated by abandonment of agricultural land. Abandoned row crop lands would provide two conditions needed for dense loblolly pine establishment: exposed mineral soil and absence of competition from hardwood rootstocks. Furthermore, the Young Pine stand, a known old-field site, was the only young forest sampled that had sufficient loblolly pine densities to produce densities seen in extant old-growth stands (assuming reasonable levels of annual mortality).

For stands that may have regenerated in response to a major disturbance or agricultural abandonment, the timing of tree establishment apparently varied. Age structures in the old-field stand (Young Pine) suggest a delayed regeneration after disturbance. This pattern has been noted in central South Carolina where tree establishment in the center of an old field was delayed thereby creating several age classes (Golley et. al., 1994). The presence of two, even-aged patches of loblolly pines in SREL Plot #4 may be the result of such a phenomenon. Alternatively, the patches in this and other stands may be the result of gap (i.e., small scale disturbance) dynamics.

In at least some stands, gap dynamics appear to be a key to loblolly pine dynamics. In the oldest stands studied (especially Weston Lake), single tree replacement has apparently occurred. This contradicts findings by Harcombe and Marks (1978) who believed that gaps from 0.05-.3 ha were necessary for tree regeneration in southeastern mesic forests. To support or refute Harcombe and Marks, further investigation into the ages of all loblolly pine in each stand will be needed. However, results from this study suggest that loblolly pine is capable of being a gap species and will perpetuate itself in the Congaree for an extended period of time or until another stand replacement event occurs. As this maintenance of loblolly is carried out, loblolly will begin to replicate the position it held in the pre-settlement forest, i.e., scattered individuals and small clusters.

LITERATURE CITED

Arno, S. F. and K. M. Sneck. 1977. A method for determining fire history in coniferous forests of the mountain west. USDA Forest Service General Technical Report INT-42. 28 pp.

Ashe, W. W. 1915. Loblolly or North Carolina Pine. North Carolina Geological and Economic Survey Bulletin No. 24. Raleigh, NC. 176 p.

Christensen, N. L. 1981. Fire regimes in southeastern ecosystems. In: H. A. Mooney, T.M. Bonnicksen, N. L. Christensen, J. E. Lotan, and W. A. Reiners, eds. Fire regimes and ecosystem properties. U. S. Forest Service General Technical Report WO-26.

Dennis, J. V. 1975. The climax forest of the Congaree Swamp. Sierra Club Bulletin pp. 31-34.

Foster, D. R. 1988. Species and stand response to catastrophic wind in central New England, U.S.A. Journal of Ecology 76:35-51.

Garren, K. H. 1943. Effects of fire on vegetation of the southeastern United States. Botanical Review 9:617-654.

Golley, F. B., J. E. Pinder III, P. J. Smallidge, and N. J. Lambert. 1994. Limited invasion and reproduction of loblolly pines in a large South Carolina old field. Oikos 69:21-27.

Grano, C. X. 1949. Is litter a barrier to the initial establishment of shortleaf and loblolly pine production? Journal of Forestry 47: 544-548.

Harcombe, P. A. and P. L. Marks. 1978. Tree diameter distributions and replacement processes in southeast Texas forests. Forest Science 24(2): 153-166.

Harper, R.M. 1943. Forests of Alabama. Geological Survey of Alabama Monograph 10, Univ. of Alabama.

Heinselman, M. L. 1973. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quaternary Research 3:329-382.

Helm, A. C., N. S. Nichols, S. M. Zedaker, and S. T. Young. 1991. Maritime forests on Bull Island, Cape Romain, South Carolina. Bulletin of the Torrey Botanical Club 118(2):170-175.

Henry, J. D. and J. M. A. Swan. 1974. Reconstructing forest history from live and dead material - an approach to the study of forest succession in southwest New Hampshire. Ecology 55:1029-1044.

Kovacik, C. F. and J. J. Winberry. 1987. South Carolina: A Geography. Westview Press. Boulder, CO.

Lorimer, C. G. 1985. Methodological considerations in the analysis of forest disturbance history. Canadian Journal of Forest Research 15:200-213.

Mohr, C. 1896. The Timber Pines of the Southern United States. USDA Division of Forestry Bulletin No. 13. Washington, DC. 160 p.

Oliver, C. D. 1981. Forest development in North America following major disturbances. Forest Ecology and Management 3:153-168.

Peet, R. K. and N. L. Christensen. 1987. Competition and tree death. BioScience 37(8):586-595.

Putz, F. E., and R. R. Sharitz. 1991. Hurricane damage to old-growth forest in Congaree Swamp National Monument, South Carolina, U.S.A. Canadian Journal of Forest Research 21:1765-1770.

Quarterman, E. and C. Keever. 1962. Southern mixed hardwood forest: climax in the southeastern Coastal Plain, USA. Ecological Monographs 32:167-185.

Ramsay, D. 1909. The History of South Carolina, from its first settlement in 1670, to the year 1880. Published by David Longworth for the author. Charleston, SC.

Romme, W. H. 1982. Fire and Landscape diversity in subalpine forests of Yellowstone National Park. Ecological Monographs 52(2):199-221.

Simms, W. G. 1840. The History of South Carolina, from its first European discovery to its erection into a republic: with a supplementary chronicle of events to the present time. Published by S. Babcock. Charleston, SC.

Smathers, G. A. 1980. Congaree Swamp National Monument vegetation type map. NPS SE Region Res./Resources Man. Rep. No. 36.

Somers, G. L., R. G. Oderwald, W. R. Harms, O. G. Langdon. 1980. Predicting mortality with a Weibull distribution. Forest Science 26(2):291-300.

Stalter, R. 1971. Age of a mature (Pinus taeda) stand in South Carolina. Ecology 52:532-533.

Swails, L. F., W. D. Anderson, W. T. Batson. 1957. A mature pine stand in the Congaree bottom land. University of South Carolina Publications Biology Series III. 2(2):82-89.

Tannehill, I. R. 1952. Hurricane - Their nature and history-particularly those of the West Indies and southern coasts of the United States. Princeton University Press. Princeton, NJ.

Table 1. Summary of microsite conditions, overstory vegetation type (from Smathers, 1980), and Hurricane Hugo visual overstory disturbance intensity for each stand.

Stand	Microsite Conditions	Vegetation Type	Hurricane Damage
Cedar Creek (CC)	creek floodplain	loblolly-swamp tupelo	intermediate
Elevated Boardwalk (EB)	floodplain - bluff ecotone	loblolly-swamp tupelo	low
Kingsnake Trail (KS)	floodplain - slough ecotone	loblolly-bottomland hardwoods	moderate
SREL Plot #4 (SR)	floodplain + shallow slough	loblolly-bottomland hardwoods	intermediate
Tall Pines (TP)	floodplain	loblolly-bottomland hardwoods	moderate
Weston Lake (WL)	bottomland ridges	loblolly-bottomland hardwoods	intermediate
Young Pine (YP)	floodplain - bluff ecotone	loblolly-bottomland hardwoods	low

Table 2. Corrected ages of *Pinus taeda* with 95% confidence intervals (CI). Lack of CI indicates an increment core that hit the pith.

CEDAR CREEK		ELEVATED BOARDWALK		KINGSNAKE TRAIL		SAVANNAH RIVER	
Tree #	AGE (yrs)	Tree #	AGE (yrs)	Tree #	AGE (yrs)	Tree #	AGE (yrs)
50	83±3	806	169±7	66	122±4	616	82±3
53	83±3	805	171±7	81	125±4	633	84±3
56	88±3	804	175±7	85	125±17	812	96±3
47	121±17	809	189±7	22	128±4	215	141±4
41	124±4			74	132±4	7X	150±15
48	124±4			89	134±4	23	157±4
42	133±4			64	137±4	434	167
49	157			71	139±4		
				79	140±4		
				86	150±4		
				88	153±4		
				70	156±4		

Table 3. Corrected ages of *Pinus taeda* with 95% confidence intervals (CI). Lack of CI indicates an increment core that hit the pith.

WESTON LAKE		TALL PINES		YOUNG PINE			
Tree #	Age (yrs)	Tree #	Age (yrs)	Tree #	Age (yrs)	Tree #	Age (yrs)
829	114±4	38	136±4	148	33±3	394	60±3
839	129±17	37	137±14	140	44±3	866	61±3
827	146±4	31	138±14	156	49±3	874	61±3
834	147±4	35	139±4	886	51	893	62±3
841	152±4	28	142±4	152	51±3	852	62±3
848	153±4			144	51±3	172	63
812	155±7			168	51±3	862	63±3
817	159±7			889	51±3	858	63±3
845	175±7			164	52±3	897	67±3
822	175±7			160	52±3	870	75±3
832a	227±20			392	57±3	882	82±3
				850	58	388	108±4

Table 4. Survival of loblolly pine seedlings into the next 200 years assuming 3.3% mortality per year.

Years from 1992	Blowdown Total	Blowdown Free to grow	Logged Area Total	Logged Area Free to grow
	-----------stems per hectare-----------			
0	157	35	14	11
10	113	25	10	8
20	82	18	7	6
60	22	4	2	2
100	6	1	1	-
120	3	1	-	-
140	2	-	-	-
160	1	-	-	-
180	-	-	-	-

Table 5. Survival of loblolly pine seedlings into the next 200 years assuming 0.4% mortality per year.

Years from 1992	Blowdown Total	Blowdown Free to grow	Logged Area Total	Logged Area Free to grow
	----------stems per hectare----------			
0	157	35	14	11
10	150	34	13	11
20	145	32	13	10
60	123	27	11	9
100	105	23	9	7
120	97	22	9	7
140	90	20	8	6
160	83	18	7	6
180	76	17	7	5
200	70	16	6	5

Table 6. Loblolly pine densities at age 60 of studied stands compared with regeneration in the hurricane blowdown and logged areas adjusted to age 60 based on a presumed mortality of 0.4% per yr.

Area	Density individuals/ha
Regenerating Forests	
Logged	9
Hurricane Blowdown	27
Older Stands	
Cedar Creek	60
Elevated Boardwalk	30
Kingsnake Trail	80
SREL Plot #4	51
Tall Pines	38
Weston Lake	46
Young Pine	348

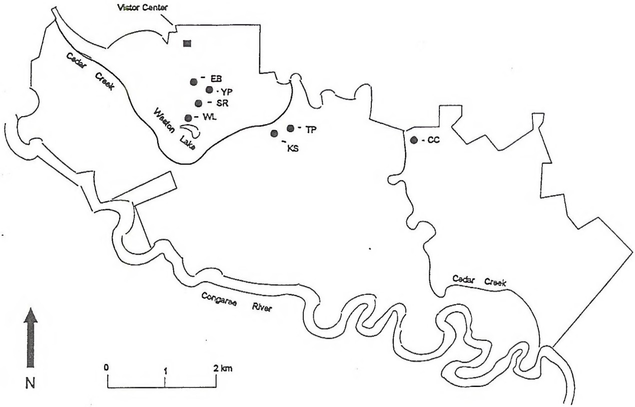

Figure 1. Map of the Congaree Swamp National Monument showing the location of the loblolly pine stands sampled. See Table 1 for key to abbreviations.

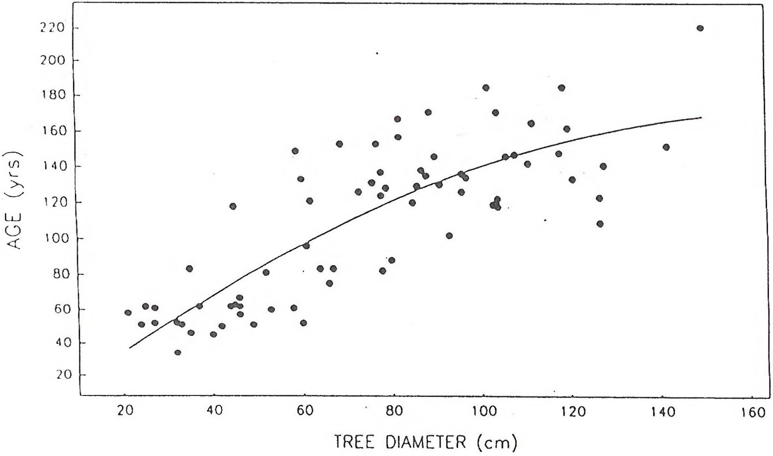

Figure 2. Age versus diameter for all loblolly pines sampled in the CSNM. Regression line shown is $y = -0.006X^2 + 2.006X - 3.08$ with an $r^2 = 0.68$.

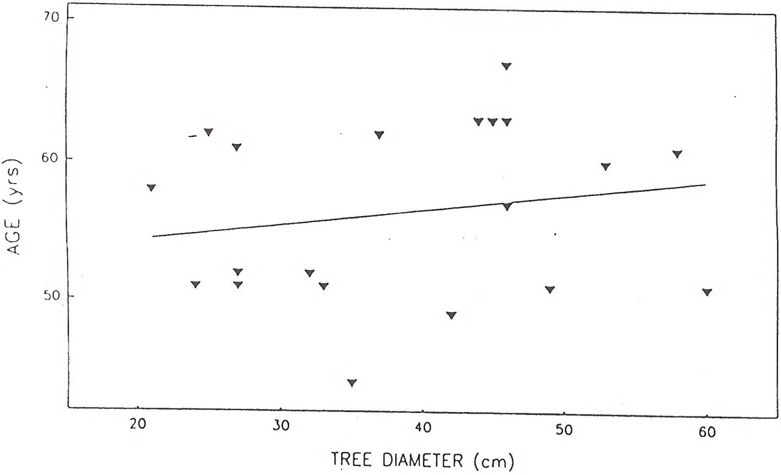

Figure 3. Age versus diameter for trees > 49 and < 67 years old in the Young Pine Stand. The simple linear regression line has a $r^2 = 0.04$.

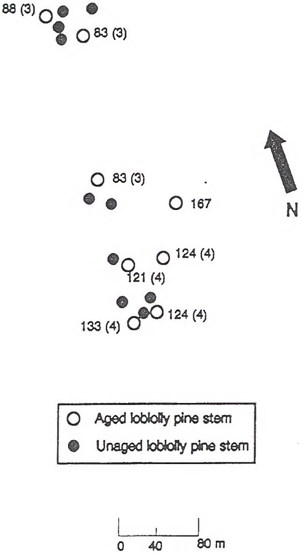

Figure 4. Spatial age distribution for the Cedar Creek Stand. Numbers in parenthesis represents the 1/2 of the 95% confidence interval width. Ages without parenthesis represent cores that hit the pith.

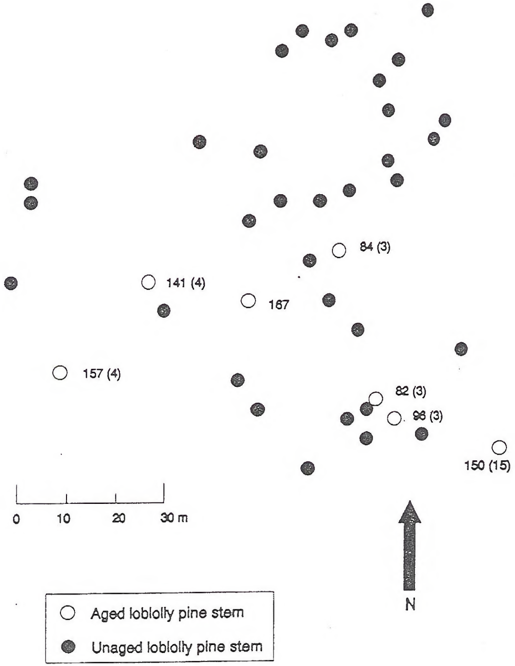

Figure 5 . Spatial age distribution for the SREL Plot #4 Stand. Numbers in parenthesis represents the 1/2 of the 95% confidence interval width. Ages without parenthesis represent cores that hit the pith.

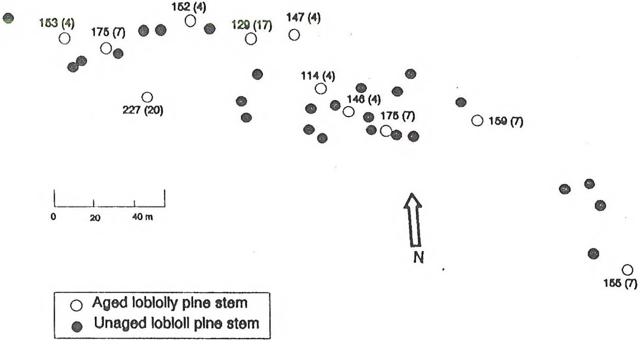

Figure 6 . Spatial age distribution for the Weston Lake Stand. Numbers in parenthesis represents the 1/2 of the 95% confidence interval width. Ages without parenthesis represent cores that hit the pith.

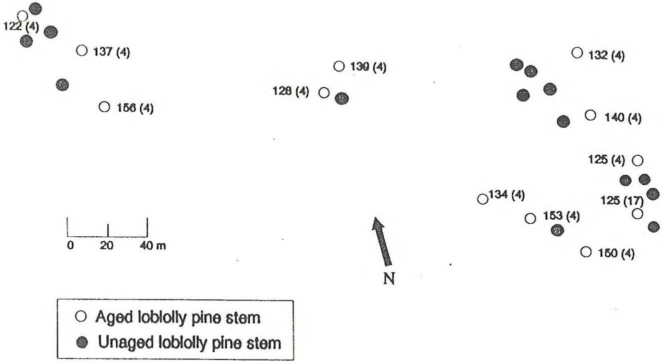

Figure 7. Spatial age distribution for the Kingsnake Trail Stand. Numbers in parenthesis represents the 1/2 of the 95% confidence interval width. Ages without parenthesis represent cores that hit the pith.

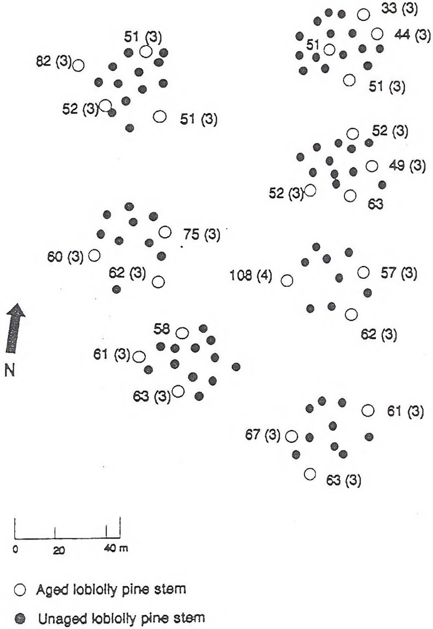

Figure 8. Spatial age distribution for the Young Pine Stand. Numbers in parenthesis represents the 1/2 of the 95% confidence interval width. Ages without parenthesis represent cores that hit the pith.

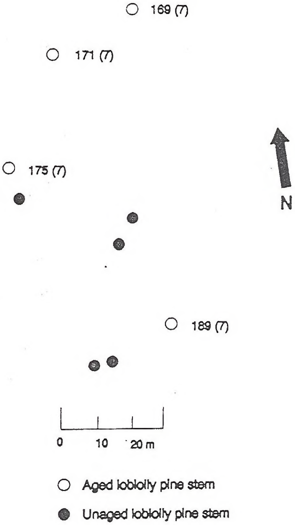

Figure 9. Spatial age distribution for the Elevated Boardwalk Stand. Numbers in parenthesis represents the 1/2 of the 95% confidence interval width. Ages without parenthesis represent cores that hit the pith.

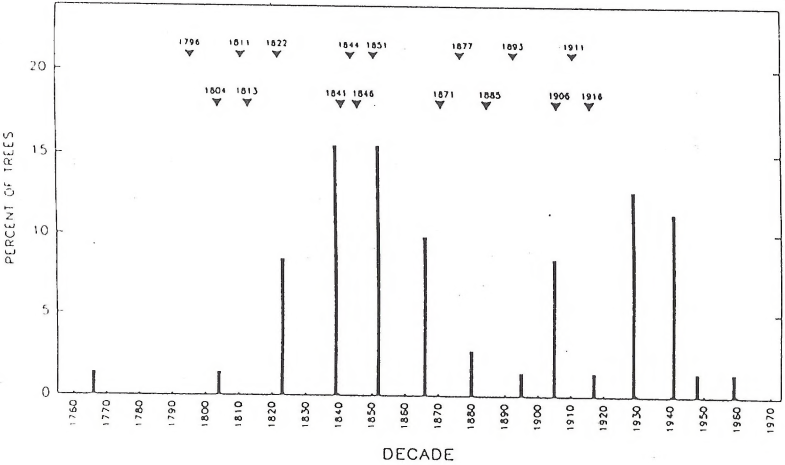

Figure 10 . Percent of stems per age class across all stands. ▾ = dates of hurricanes in South Carolina.

Table A. Tree layer (stems ≥ 10 cm at DBH) sampled on six 0.05 ha plots in Cedar Creek stand.

SCIENTIFIC NAME	# OF IND./ ha	BASAL AREA m^2/ha	FREQ.	IMPORTANCE VALUE
Pinus taeda	43	23.60	100	79.6
Ilex opaca	85	2.77	100	47.2
Liquidambar styraciflua	48	7.70	100	45.9
Carpinus caroliniana	71	1.80	100	39.8
Nyssa sylvatica var. *biflora*	28	4.29	83.3	29.9
Quercus laurifolia	12	2.51	50	16.0
Ulmus alata	6	.73	33.3	8.2
Q. michauxii	6	0.52	33.3	7.9
U. americana	9	0.22	33.3	7.2
Q. nigra	3	0.43	16.7	4.1
Carya ovata	3	0.36	16.7	3.9
Q. lyrata	3	0.19	16.7	3.6
C. cordiformis	3	0.11	16.7	3.4
Morus rubra	3	0.06	16.7	3.3
Total /ha	323	47.29		

Table B. Midstory (stems > 2.5 cm and <10.0 cm DBH) sampled at six 0.05 ha plots Cedar Creek stand.

SCIENTIFIC NAME	# OF IND./ ha	BASAL AREA m^2/ha	FREQ.	IMPORTANCE VALUE
Ilex opaca	137	0.500	100	98.3
Carpinus caroliniana	80	0.303	83.3	64.0
Asimina triloba	60	0.154	16.7	23.3
I. verticillata	20	0.051	33.3	16.4
Liquidambar styraciflua	20	0.037	33.3	15.2
Morus rubra	9	0.051	33.3	13.5
Ulmus americana	11	0.020	33.3	11.6
Quercus michauxii	9	0.026	33.3	11.3
Q. laurifolia	9	0.014	33.3	10.4
Carya ovata	9	0.005	33.3	9.7
Celtis laevigata	6	0.008	33.3	9.2
Nyssa sylvatica var. biflora	6	0.005	16.7	6.0
I. decidua	3	0.014	16.7	5.9
Q. lyrata	3	0.005	16.7	5.2
U. alata	3	0.005	16.7	5.2
Acer rubrum	3	0.003	16.7	5.0
Total	382	3.19		

Table C. Tree layer (stems ≥ 10 cm at DBH) sampled on six 0.05 ha plots in Elevated Boardwalk stand.

SCIENTIFIC NAME	# OF IND./ ha	BASAL AREA m^2/ha	FREQ.	IMPORTANCE VALUE
Pinus taeda	23	22.11	100	68.7
Nyssa sylvatica var. biflora	91	11.04	100	62.8
Carpinus caroliniana	82	1.39	100	39.1
Liquidambar styraciflua	37	6.59	83.3	36.1
Ilex opaca	60	1.39	83.3	30.3
Acer rubrum	31	2.03	83.3	24.5
Ulmus americana	17	0.59	66.7	15.2
Quercus laurifolia	14	0.60	50.0	12.0
Liriodendron tulipifera	11	0.20	33.3	8.2
Q. lyrata	3	0.03	16.7	3.1
Total	369	47.97		

Table D. Midstory (stems > 2.5 cm and <10.0 cm DBH) sampled at six 0.05 ha plots in the Elevated Boardwalk stand.

SCIENTIFIC NAME	# OF IND./ ha	BASAL AREA m_2/ha	FREQ.	IMPORTANCE VALUE
Carpinus caroliniana	145	0.431	100	70.3
Ilex opaca	133	0.465	100	70.2
Acer rubrum	70	0.119	83.3	31.0
Quercus laurifolia	48	0.113	100	26.6
Liriodendron tulipifera	28	0.093	66.7	18.5
Q. michauxii	26	0.039	66.7	14.3
Fraxinus pennsylvanica	20	0.074	50.0	13.7
Liquidambar styraciflua	14	0.039	50.0	10.3
Ulmus americana	11	0.042	50.0	9.2
Persea borbonia	9	0.008	50.0	7.0
Carya ovata	6	0.020	33.3	5.2
Nyssa sylvatica var. biflora	6	0.017	33.3	5.0
Q. nigra	6	0.008	33.3	4.5
U. alata	3	0.011	16.7	3.2
Q. lyrata	3	0.011	16.7	3.2
Q. phellos	3	0.003	16.7	2.6
Rhododendron spp.	3	0.003	16.7	2.6
Cornus stricta	3	0.003	16.7	2.6
Total	537	3.50		

Table E. Tree layer (stems ≥ 10 cm at DBH) sampled at six 0.05 ha plots in the Kingsnake Trail stand.

SCIENTIFIC NAME	# OF IND./ ha	BASAL AREA m^2/ha	FREQ.	IMPORTANCE VALUE
Pinus taeda	198	42.94	100	120.5
Liquidambar styraciflua	41	12.73	83.3	41.5
Ilex opaca	53	1.76	83.3	31.1
Carpinus caroliniana	47	1.09	83.3	26.1
Celtis laevigata	22	0.84	67.7	15.2
Ulmus alata	19	1.44	67.7	15.2
U. americana	16	1.21	50.0	11.6
Asimina triloba	19	0.26	50.0	11.1
Quercus michauxii	9	0.16	50.0	9.0
Carya cordiformis	6	0.18	33.3	5.6
Q. laurifolia	3	0.18	16.7	5.6
Morus rubra	3	0.30	16.7	2.7
Nyssa sylvatica var. biflora	3	0.27	16.7	2.6
Fraxinus pennsylvanica	3	0.03	16.7	2.2
Total	442	63.39		

Table F. Midstory (stems > 2.5 cm and <10.0 cm DBH) sampled at six 0.05 ha plots in the Kingsnake Trail stand.

SCIENTIFIC NAME	# OF IND./ ha	BASAL AREA m^2/ha	FREQ.	IMPORTANCE VALUE
Asimina triloba	414	0.031	100	123.0
Carpinus caroliniana	101	0.333	83.3	49.1
Ilex opaca	66	0.267	83.3	29.6
Celtis laevigata	47	0.163	66.7	27.5
Ulmus alata	9	0.038	50.0	11.5
Quercus nigra	9	0.034	50.0	11.4
Q. michauxii	9	0.031	33.3	9.5
Fraxinus pennsylvanica	6	0.038	33.3	9.5
U. americana	6	0.031	33.3	9.0
Ilex decidua	12	0.031	16.7	6.2
Carya cordiformis	6	0.003	33.3	6.2
Crategus spp.	3	0.016	16.7	4.0
C. ovata	3	0.006	16.7	3.5
Total	691	3.02		

Table G. Tree layer (stems ≥ 10 cm at DBH) sampled at six 0.05 ha plots in the SREL Plot #4 stand.

SCIENTIFIC NAME	# OF IND./ ha	BASAL AREA m^2/ha	FREQ.	IMPORTANCE VALUE
Pinus taeda	40	14.59	100	62.6
Carpinus caroliniana	97	1.46	100	45.8
Liquidambar styraciflua	41	7.81	100	45.0
Quercus phellos	38	8.07	100	45.5
Q. laurifolia	37	5.37	50.0	31.2
Nyssa sylvatica var. biflora	34	1.23	50.0	21.1
Acer rubrum	17	0.86	50.0	14.1
Ilex opaca	16	0.36	50.0	12.5
Q. michauxii	4	0.10	50.0	8.6
Ulmus alata	7	0.32	16.7	7.4
Q. nigra	2	0.21	16.7	3.4
U. americana	1	0.06	16.7	2.8
Total	334	40.44		

Table H. Midstory (stems > 2.5 cm and <10.0 cm DBH) sampled at six 0.05 ha plots in the SREL Plot #4 stand.

SCIENTIFIC NAME	# OF IND./ ha	BASAL AREA m^2/ha	FREQ.	IMPORTANCE VALUE
Carpinus caroliniana	93	0.030	66.7	101.3
Ilex opaca	33	0.031	66.7	53.4
Liquidambar styraciflua	6	0.028	16.7	27.7
Ulmus alata	5	0.024	16.7	24.5
Acer rubrum	12	0.013	16.7	22.0
Nyssa sylvatica var. biflora	2	0.015	16.7	18.0
Quercus michauxii	2	0.007	16.7	12.8
I. decidua	4	0.003	16.7	11.7
U. americana	1	0.004	16.7	10.4
Fraxinus pennsylvanica	1	0.002	16.7	9.2
Q. phellos	1	0.001	16.7	9.0
Total	160	2.16		

Table I. Tree layer (stems ≥ 10 cm at DBH) sampled at six 0.05 ha plots in the Tall Pines stand.

SCIENTIFIC NAME	# OF IND./ ha	BASAL AREA m^2/ha	FREQ.	IMPORTANCE VALUE
Pinus taeda	32	19.48	100	76.1
Liquidambar styraciflua	35	5.96	100	42.3
Ulmus americana	35	3.15	83.3	37.2
Celtis laevigata	25	5.39	83.3	21.8
Carpinus caroliniana	22	0.38	83.3	20.1
Ilex opaca	22	1.13	33.3	16.1
Fraxinus pennsylvanica	12	0.87	50.0	13.6
U. alata	16	0.36	50.0	13.4
Acer rubrum	12	0.61	50.0	12.9
Quercus michauxii	9	0.16	50.0	10.4
Q. lyrata	3	1.87	16.7	8.4
Asimina triloba	9	0.11	33.3	8.2
Q. nigra	3	0.54	16.7	4.8
Morus rubra	3	0.32	16.7	4.2
Carya aquatica	3	0.13	16.7	3.7
Ilex decidua	3	0.03	16.7	3.4
Crategus spp.	3	0.04	16.7	3.4
Total	247	40.53		

Table J. Midstory (stems > 2.5 cm and <10.0 cm DBH) sampled at six 0.05 ha plots in the Tall Pines stand.

SCIENTIFIC NAME	# OF IND./ ha	BASAL AREA m^2/ha	FREQ.	IMPORTANCE VALUE
Asimina triloba	492	0.907	100	126.6
Celtis laevigata	57	0.214	100	34.1
Ilex decidua	85	0.223	66.7	34.0
Carpinus caroliniana	41	0.120	83.3	24.6
Ilex americana	32	0.139	66.7	15.0
Morus rubra	9	0.022	50.0	8.8
Carya cordiformis	9	0.013	50.0	8.3
Quercus nigra	6	0.044	33.3	7.5
Liquidambar styraciflua	25	0.022	16.7	6.5
Q. laurifolia	6	0.009	33.3	6.3
Ulmus alata	6	0.013	33.3	5.8
U. americana	6	0.009	33.3	5.6
Crategus spp.	6	0.009	33.3	5.6
C. ovata	6	0.006	33.3	5.3
Fraxinus pennsylvanica	6	0.006	16.7	3.2
Acer rubrum	3	0.003	16.7	2.8
Total	795	3.76		

Table K. Tree layer (stems ≥ 10 cm at DBH) sampled at six 0.05 ha plots in the Weston Lake stand.

SCIENTIFIC NAME	# OF IND./ ha	BASAL AREA m^2/ha	FREQ.	IMPORTANCE VALUE
Pinus taeda	38	25.04	100	76.1
Liquidambar styraciflua	35	12.00	83.3	48.1
Carpinus caroliniana	50	1.07	100	34.6
Quercus laurifolia	19	7.28	50.0	27.6
Nyssa sylvatica var. biflora	25	1.637	66.7	21.7
Celtis laevigata	22	0.48	83.3	20.6
Fraxinus pennsylvanica	16	1.40	50.0	15.3
Ilex opaca	19	0.67	50.0	15.2
Ulmus americana	19	0.98	33.3	13.4
Acer rubrum	6	1.21	33.3	9.2
U. alata	6	0.27	33.3	7.4
Q. michauxii	3	0.06	16.7	3.6
Morus rubra	3	0.06	16.7	3.6
Asimina triloba	3	0.03	16.7	3.6
Total	264	52.19		

Table L. Midstory (stems > 2.5 cm and <10.0 cm DBH) sampled at six 0.05 ha plots in the Weston Lake stand.

SCIENTIFIC NAME	# OF IND./ ha	BASAL AREA m^2/ha	FREQ.	IMPORTANCE VALUE
Carpinus caroliniana	41	0.186	83.3	91.4
Asimina triloba	85	0.189	50.0	52.8
Celtis laevigata	41	0.120	66.7	32.7
Ilex decidua	25	0.079	66.7	26.1
Quercus michauxii	22	0.082	50.0	22.2
Ulmus americana	12	0.100	33.3	21.4
I. opaca	16	0.069	33.3	18.0
Q. laurifolia	9	0.006	50.0	11.8
U. alata	6	0.009	33.3	8.8
Nyssa sylvatica var. biflora	3	0.028	16.7	6.6
Fraxinus caroliniana	3	0.006	16.7	4.1
Morus rubra	3	0.006	16.7	4.1
Total	266	2.88		

Table N. Midstory (stems > 2.5 cm and <10.0 cm DBH) sampled at six 0.05 ha plots in the Young Pine stand.

SCIENTIFIC NAME	# OF IND./ ha	BASAL AREA m^2/ha	FREQ.	IMPORTANCE VALUE
Liquidambar styraciflua	387	1.522	100	89.7
Acer rubrum	349	0.652	100	59.9
Ilex opaca	160	0.394	100	36.3
Carpinus caroliniana	72	0.151	66.7	17.9
Cornus florida	22	0.085	66.7	11.7
Ulmus alata	19	0.085	66.7	11.5
Nyssa sylvatica var. biflora	47	0.120	33.3	11.1
Quercus laurifolia	19	0.057	66.7	10.6
Q. nigra	16	0.028	66.7	9.5
Fagus grandifolia	22	0.069	50.0	9.3
I. decidua	22	0.047	50.0	8.6
Rhododendron spp.	38	0.038	33.3	7.9
Q. phellos	12	0.035	50.0	7.4
Q. michauxii	6	0.003	33.3	4.2
Prunus serotina	3	0.003	16.7	2.2
I. veticillata	3	0.003	16.7	2.2
Total	1,197	5.29		

BLM LIBRARY
RS 150A BLDG. 50
DENVER FEDERAL CENTER
P.O. BOX 25047
DENVER, CO 80225